

L2 Earth Atmosphere Observatory: Formation Guidance, Metrology, and Control Synthesis

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Extended Abstract

This paper discusses the results of research sponsored by the NASA Revolutionary Aerospace Systems Concepts (RASC) program, and includes the synthesis and analysis of the guidance, metrology and control for a two-spacecraft formation in a unique continuously powered orbit near the Sun-Earth L2 Lagrange point observing the illuminated atmosphere of the Earth while it is continuously occulting the Sun.

The L2 Earth Atmosphere Observatory is a unique concept that will improve the understanding of dynamic mechanisms that cause changes in the atmosphere, and can advance the development of models and techniques to predict short and long-term climate changes. Earth's atmosphere is placed into a permanent solar occultation when viewed from the observatory station-keeping on the oscillating Sun-Earth/Moon Barycenter line at approximately 1.5 million km from the Earth. Long-term climate change studies are made uniquely possible by the ability to continuously view with high spatial and spectral resolution the atmospheric chemistry of the entire earth from this vantage point.

The observatory formation is composed of a Secondary rotating Telescope spacecraft, pointed at a 25-meter membrane mirror on a Primary Aperture spacecraft 125-meters distant on-axis, that scans the focused annular image of the illuminated atmosphere of the Earth reflected from the large mirror. Figures 1 and 2 depict this unique concept.

The paper presents the orbital analyses and on-board trajectory guidance and formation positioning control designs that employ mission-specific metrology and sensor designs including:

- Formation RF Range and Bearing Metrology
- Formation Laser Range and Bearing Metrology
- Sun-Earth Orbit Tracking Sensor
- Primary Mirror Surface-Figure Sensor
- Primary Mirror Center-of-Curvature Sensor

The continuously powered orbit following requirements of the science mission place severe mass and power constraints on the spacecraft designs. To achieve a practical configuration high efficiency and high specific impulse propulsion technology is

employed. Both spacecraft utilize advanced Xenon Ion Electric Propulsion (EP) Thrusters for occultation orbit following and formation precision positioning control. The inherently non-linear EP thrusters are used for translation control, and reaction wheels are used for attitude control. Two sets of thrusters for translation control are used, i.e. *large (30 cm diameter) and small (10 cm diameter) thrusters*. Large thrusters provide feed-forward control forces as well as orbital error feedback forces in the radial-tangential plane normal to the Sun-Earth Line. Small thrusters provide formation relative control forces, orbital feed-forward and error feedback forces in the Sun-Earth Line direction (which are an order smaller than radial and tangential components).

The control strategy to track the desired orbit and to maintain fine (millimeter precision) formation relative control is described. The approach is based on using multivariable PID with feed-forward control structures for translation and attitude control. The orbit following and formation control problems are independently solved. This is primarily done because of the much tighter control requirements for formation control than orbit control (accuracy in kilometers). Therefore, the closed loop responses of both systems have different spatial and temporal scales, which makes our design approach practical. We also present simulation trade studies, where the desired performances can be achieved in the presence of specified EP thruster non-linearity (throttle step size, and plasma instability at low thrust levels), and sensor noise.

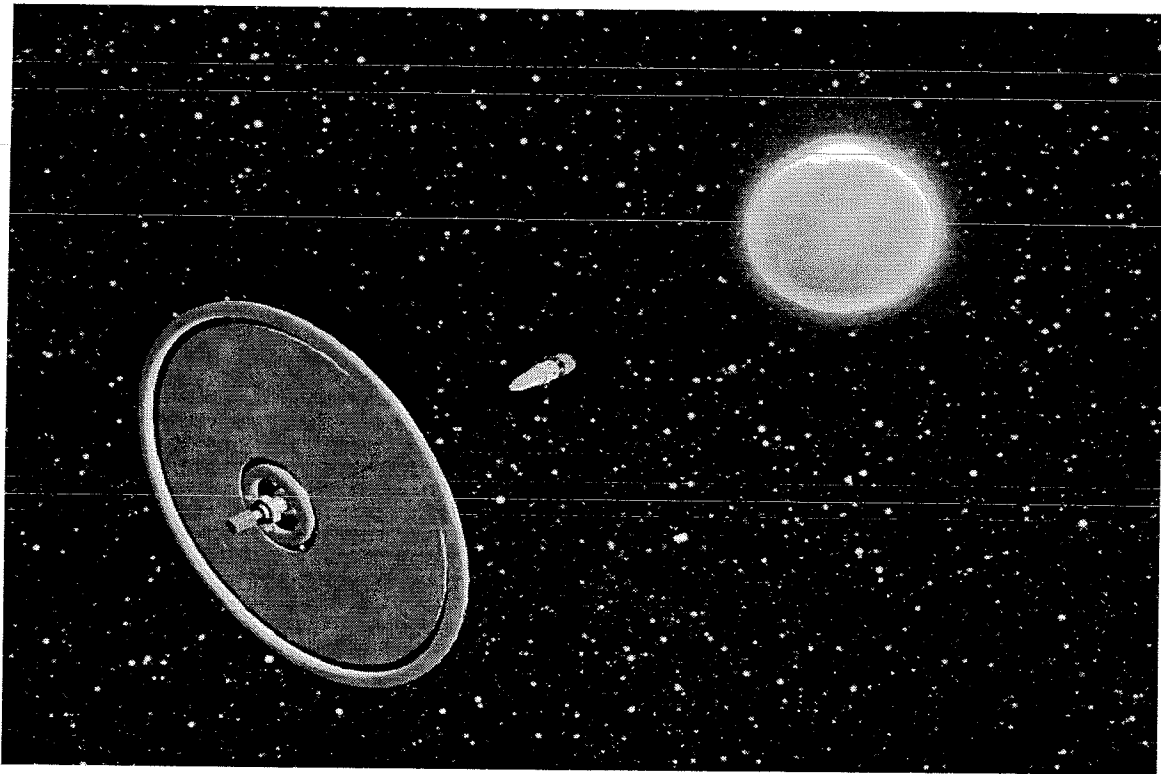


Figure 1: Sun-Earth Occultation Atmosphere Observatory Concept

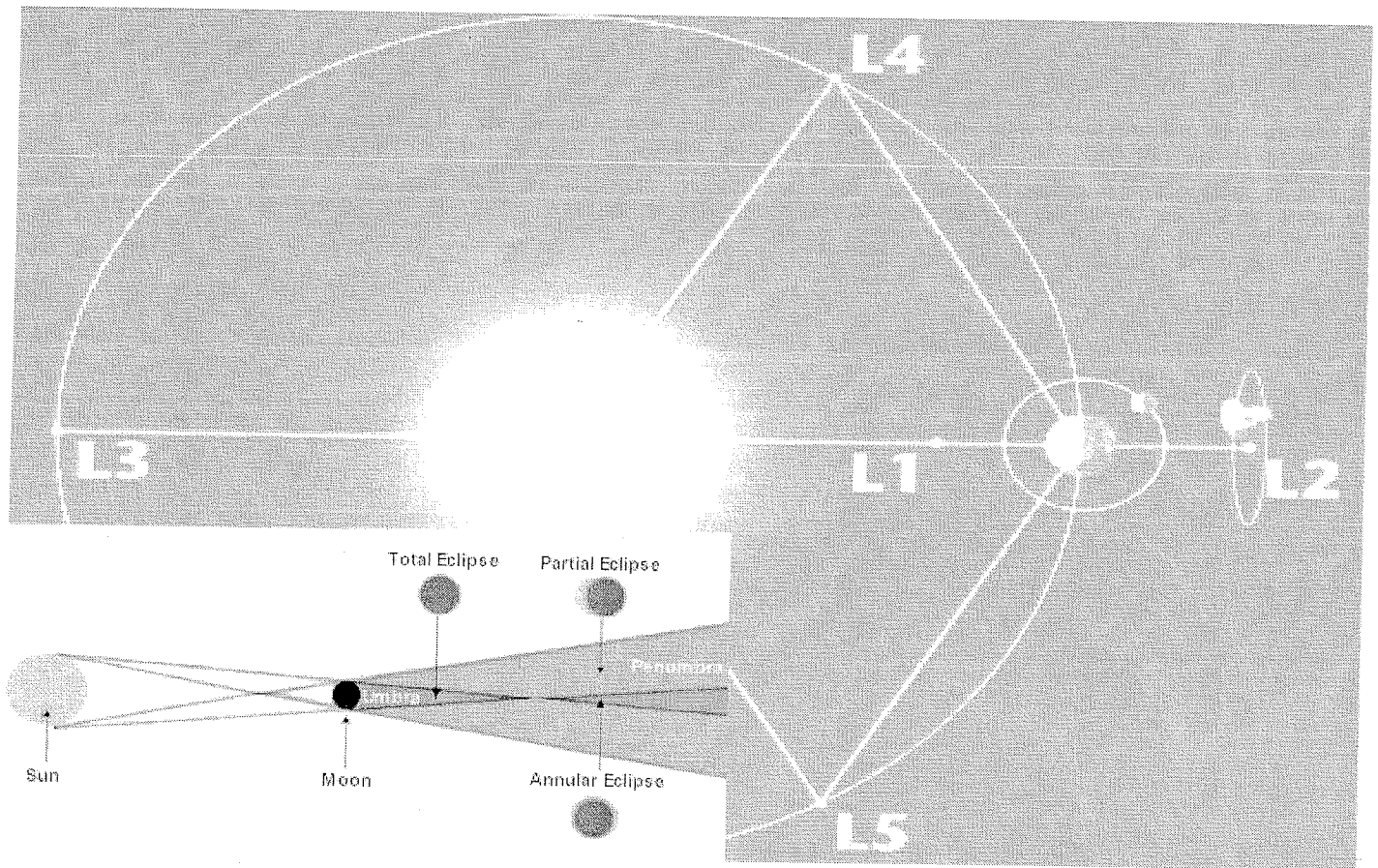


Figure 2: Observatory Orbital Geometry at L2